MANIPAL
ACADEMY of HIGHER EDUCATION
(Institution of Eminence Deemed to be University)

International Space Drone Challenge 2025

Manipal Academy of Higher Education

Project MANAS

The Offical AI & Robotics Team of MAHE

System Design and Development Review

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1. INTRODUCTION

Project MANAS, the official AI and Robotics Team of *Manipal Academy of Higher Education (MAHE)*, proudly presents the report for the System Design and Development Review stage of *SPROS International Space Drone Challenge (ISDC)* 2025. This report documents our approach to this year's problem statement, providing insights into the strategies adopted for drone development, project management, resource allocation and risk assessment.

2. PROJECT MANAGEMENT

2.1. *Team Organizational Structure*

Project Manas comprises a team of 41 interdisciplinary engineering undergraduates, aiming to solve problems in the field of AI & Robotics, with a focus on autonomous systems. We are organised into four subsystems:

- *Artificial Intelligence*: Responsible for the design and development of the software stack.
- *Sensing and Automation*: Handles power distribution, motor control, and integration of the sensor suite onboard our systems.
- *Mechanical*: Facilitates the development of innovative mechanical designs and ensures precision in manufacturing processes.
- *Management*: Oversees project finances, logistics, public relations, and communications with institutional stakeholders and external sponsors.

The team is headed by a board composed of the Team Manager, the Technical Head, the R&D Head and respective Subsystem heads. Integration of all the subsystems is ensured through regular team meetings, facilitating effective collaboration and communication. To streamline our approach to this year's edition of ISDC, a subset of our team was created, with members spanning across all 4 subsystems, organised as below:

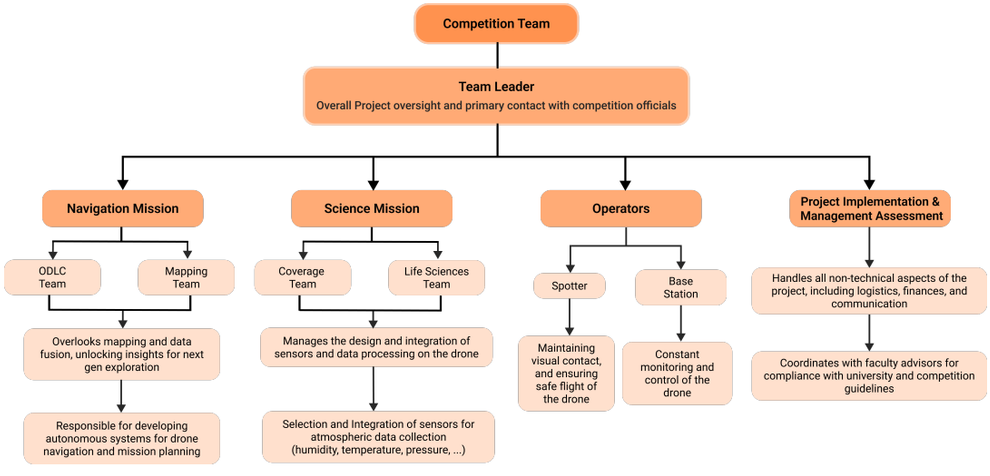

Competition Team
Team Leader
Overall Project oversight and primary contact with competition officials
Navigation Mission
Science Mission
Operators
Project Implementation & Management Assessment
ODLC Team
Mapping Team
Coverage Team
Life Sciences Team
Spotter
Base Station
Handles all non-technical aspects of the project, including logistics, finances, and communication
Overlooks mapping and data fusion, unlocking insights for next gen exploration
Manages the design and integration of sensors and data processing on the drone
Maintaining visual contact, and ensuring safe flight of the drone
Constant monitoring and control of the drone
Coordinates with faculty advisors for compliance with university and competition guidelines
Responsible for developing autonomous systems for drone navigation and mission planning
Selection and Integration of sensors for atmospheric data collection (humidity, temperature, pressure, ...)

Figure 2: Team Organizational Structure

2.2. *Team Recruitment Process*

Recruitments at *Project MANAS* happen annually. First-year students are made aware of our team's mission statement, ongoing projects and subsystems, following which they can apply via a one-on-one interview or online recruitment challenges on our website. Selected candidates enter a six-month task phase where they receive hands-on training in their respective subsystems under the dedicated mentorship of members of the team.

2.3. *Budget and Resource Management*

Items	Quantity	Total Price (INR)
Frame	1	25,257
Communication Devices	4	87,408
Science Mission Sensors	5	21,451
Propulsion	12	64,635
Flight Controller	1	46,632
GPS	2	39,400
Imaging	2	46,298
Power Distribution	1	7,545
TOTAL		**3,38,356**

Table 1: Budget Allocation

Our strategy for resource management focused on maximising efficiency and minimising waste at every stage of the project. Collaborative tools like *Slack* and *Google Docs* were used for weekly progress reports and real-time updates, ensuring the team's transparency and accountability. Direct purchase from wholesale vendors and material reuse, such as repurposing chassis parts from previous prototypes helped reduce costs.

- Communication includes Telemetry Radio, RC Controller and Rocket AC.
- Propulsion includes Motors, Propellers and ESC's.
- Imaging includes Raspberry Pi and Camera.

Project MANAS is established as a Major Student Project under *MAHE*, by virtue of which we are allocated an annual budget by the university based on our proposed plan of action for the financial year. This provides us with strong financial grounding to pursue our endeavours, aimed at pushing the limits in the field of AI & Robotics. A subset of our annual budget was allocated towards ISDC'25, amounting to 400,000 INR. This, coupled with our total secured sponsorship brought our budget to 464,000 INR. As detailed in Table 1, our total expenditure amounted to 338,356 INR, which is 125,644 INR below the allocated budget.

2.4. *Project Planning*

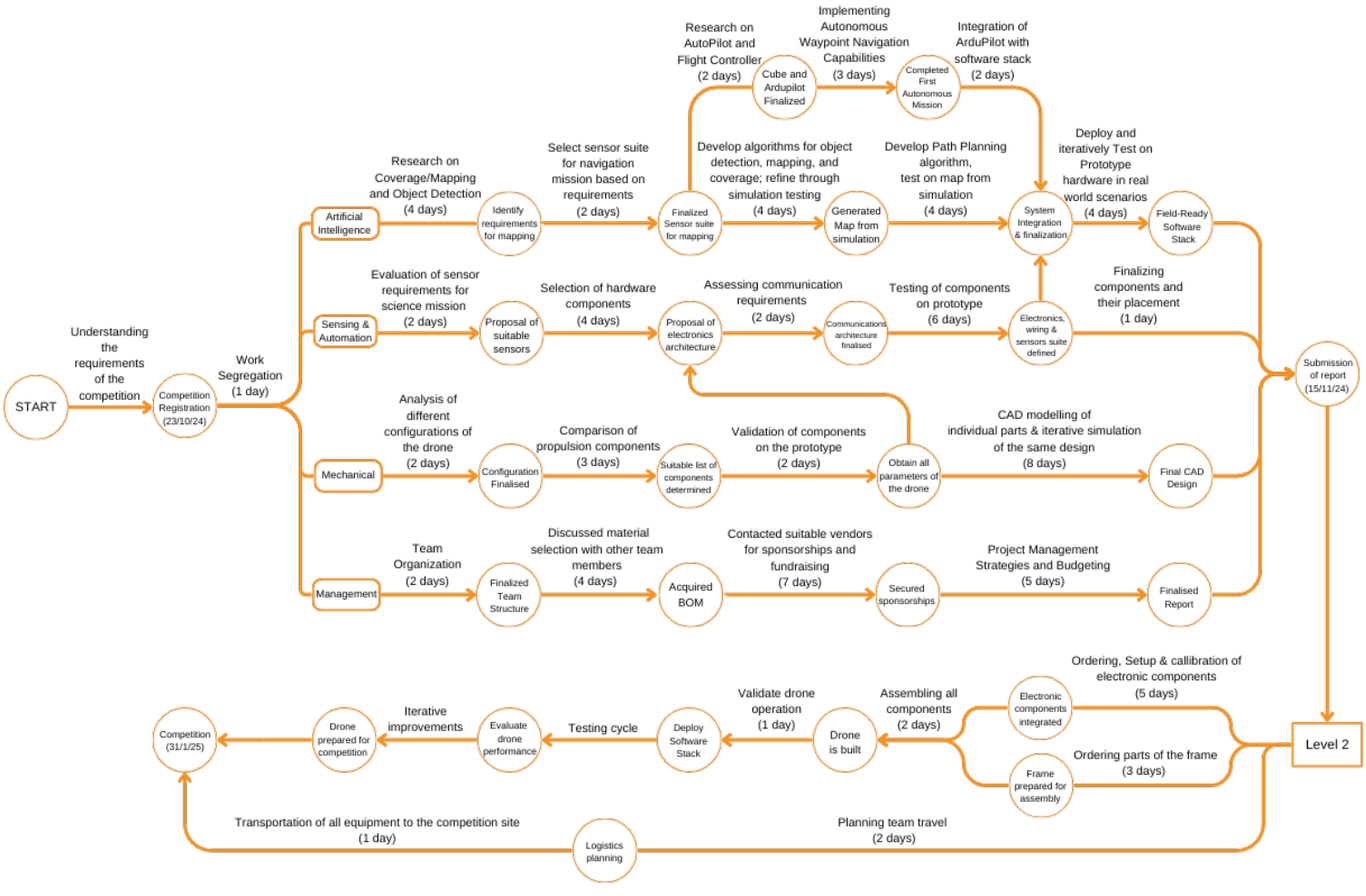

START
Understanding the requirements of the competition
Competition Registration (23/10/24)
Work Segregation (1 day)
Artificial Intelligence
Research on Coverage/Mapping and Object Detection (4 days)
Identify requirements for mapping
Select sensor suite for navigation mission based on requirements (2 days)
Finalized Sensor suite for mapping
Research on AutoPilot and Flight Controller (2 days)
Cube and Ardupilot Finalized
Implementing Autonomous Waypoint Navigation Capabilities (3 days)
Completed First Autonomous Mission
Integration of ArduPilot with software stack (2 days)
Develop algorithms for object detection, mapping, and coverage; refine through simulation testing (4 days)
Generated Map from simulation
Develop Path Planning algorithm, test on map from simulation (4 days)
System Integration & finalization
Deploy and iteratively Test on Prototype hardware in real world scenarios (4 days)
Field-Ready Software Stack
Sensing & Automation
Evaluation of sensor requirements for science mission (2 days)
Proposal of suitable sensors
Selection of hardware components (4 days)
Proposal of electronics architecture
Assessing communication requirements (2 days)
Communications architecture finalised
Testing of components on prototype (6 days)
Electronics, wiring & sensors suite defined
Finalizing components and their placement (1 day)
Mechanical
Analysis of different configurations of the drone (2 days)
Configuration Finalised
Comparison of propulsion components (3 days)
Suitable list of components determined
Validation of components on the prototype (2 days)
Obtain all parameters of the drone
CAD modelling of individual parts & iterative simulation of the same design (8 days)
Final CAD Design
Management
Team Organization (2 days)
Finalized Team Structure
Discussed material selection with other team members (4 days)
Acquired BOM
Contacted suitable vendors for sponsorships and fundraising (7 days)
Secured sponsorships
Project Management Strategies and Budgeting (5 days)
Finalised Report
Submission of report (15/11/24)
Level 2
Ordering, Setup & callibration of electronic components (5 days)
Electronic components integrated
Ordering parts of the frame (3 days)
Frame prepared for assembly
Assembling all components (2 days)
Drone is built
Validate drone operation (1 day)
Deploy Software Stack
Testing cycle
Evaluate drone performance
Iterative improvements
Drone prepared for competition
Competition (31/1/25)
Transportation of all equipment to the competition site (1 day)
Logistics planning
Planning team travel (2 days)

Figure 3: PERT Chart

2.5. *Fundraising and Sponsorship Plans*

To enable our participation in this year's competition, securing additional sponsorship was key and our approach to the same is highlighted below:

EVALUATING OUR REQUIREMENTS
FINDING SUITABLE COMPANIES
FINDING ALUMNI/POCs FOR THE COMPANY
COLD EMAILING TO THE POCs
MAKE NEGOTIATIONS & DISCUSS QUTOTAIONS

Figure 4: Sponsorship Process

A major challenge in developing our drone was the high cost of motors, propellers, and ESCs. After evaluating our potential suppliers, we secured a generous 40% sponsorship from *T-MOTORS*, saving INR 43,000.

During simulation testing, we faced power reliability issues, leading to data loss and delays. To resolve this, we approached *Schneider Electric*, who provided us with an Uninterruptible Power Supply (UPS) offering us a discount of 100%, i.e. INR 21,000.

Ongoing Sponsorship Initiatives:

- 3D printing serves as a key tool that enables us to maximise in-house manufacturing of components, including arm mounts, T-joints, and motor mounts. To enable this, we are presently seeking sponsorship from *Numakers* and *eSUN* for PLA + CF nylon Filaments and have initiated talks for the same.
- To effectively test our components, we require a reliable Digital Multimeter (DMM). We have approached *Fluke* through their Tool Donation Program to explore potential support for the same.

2.6. *Industrial and Educational Outreach for Public Engagement*

Project MANAS has consistently engaged in public outreach, both within and beyond our university walls, to foster interest and knowledge in the domain of AI & Robotics, with a keen focus on unmanned aerial systems.

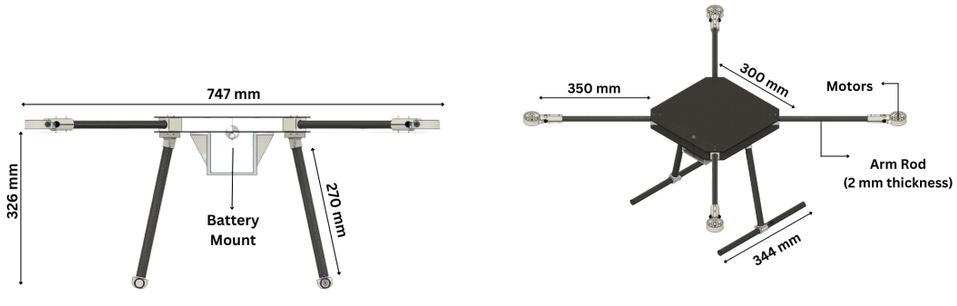
- **Public Outreach:** We organise workshops on campus for community engagement through the *Volunteer Services Organization* (VSO) and local STEM clubs, such as the *Society of Automotive Engineers, Manipal* (SAE-IM), training drone technology and control systems.
- **Industry Connect and Expert Insights:** We organised a session on "The Role of AI in Space Exploration" featuring Shreyansh Daftry, a research technologist at *NASA's Jet Propulsion Laboratory* and an alumnus of *MAHE*. Visits from leaders such as the Director General of the *National Institute of Robotics & Artificial Intelligence* strengthen our industry connections and provide insights into AI and robotics.
- **Social Media Outreach:** We maintain an active social media presence on platforms such as LinkedIn and Facebook to share project updates, design innovations, and key milestones, engaging with a wider audience.
- **Previous projects:** With a decade of dedicated experience, *Project MANAS* has continuously pushed the boundaries of autonomous technology and robotics. Our commitment to research, education, and innovation has led to significant achievements, including winning the Lescoe Cup at *IGVC*, being top contenders in *Mahindra's Rise Prize* challenge, and consistently ranking as one of the top performing teams at *AUVSI SUAS* over the past three years.

Figure 5: In-house workshops and collaborations

3. TECHNICAL ASPECTS AND SYSTEM DESIGN

3.1. *Mechanical Design*

The UAV's design, based on a quadcopter configuration, was selected for its suitability to Mars' thin atmosphere and challenging terrain while also meeting constraints related to mass, budget, and mission objectives. The quadcopter's high-speed rotors generate lift in low-density air, and its VTOL capability allows it to take off and land on uneven surfaces, offering precise control and stability—essential for the mission's short, controlled flights. A factor of safety of 4 is maintained throughout the design to ensure reliability under operational stresses. Key factors, such as motor and propeller efficiency and optimal material comparisons, are discussed below.



(a) Side view (b) Isometric View

Figure 6: Frame Design

3.1.1. *Arm Design*

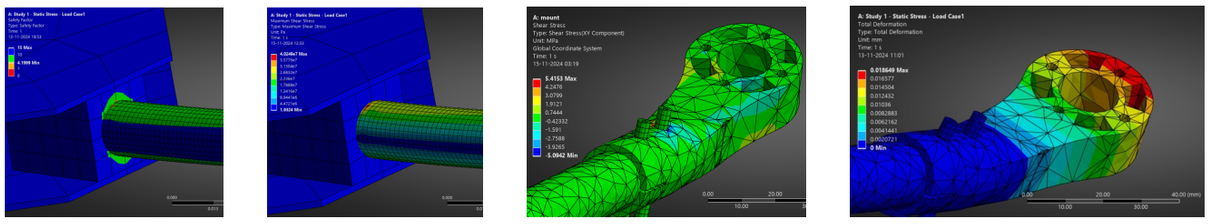
The drone's arms are constructed from circular CF rods. FEA simulations were performed with various thicknesses, out of which 2mm was selected as optimal. The 2mm thickness provided an ideal balance between rigidity and weight and attained a reasonable factor of safety at a load of 40N at the motor mount. Furthermore, Circular arms distribute stress evenly under bending and torsional loads and integrate seamlessly with our clamps.

3.1.2. *Clamping Mechanism*

The arm mounts are designed around a clamping mechanism that utilises compressive forces to hold each CF rod in place. They are 3D printed from CF-nylon. Each mount features two bolts that apply uniform compression, ensuring stable fixation under loads. This mechanism was chosen for its reliability and ease of assembly, allowing for rapid deployment while minimising points of failure in high-stress conditions(Refer to Figures 7a and 7b).

3.1.3. *Motor mount*

The motor mount was designed with vents to enhance ventilation and prevent motor overheating by providing better air flow, which helps to dissipate the heat generated during operation. Proper cooling also helps to reduce the thermal stresses on the mount and motor. We have chosen CF nylon for the motor mount due to its superior heat resistance compared to other materials. The motor mount slides onto the arm rod and is held in place by 2 M4 bolts.



(a) FOS (Clamp) (b) Shear Stress (Clamp) (c) Shear Stress (Motor Mount) (d) Total Deformation (Motor Mount)

Figure 7: Clamping Mechanism and Motor Mount

3.1.4. *Battery Mount*

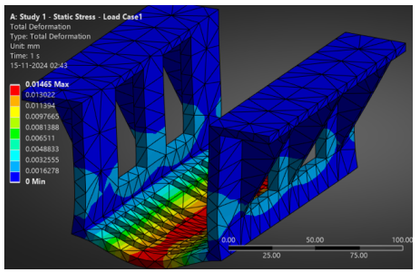
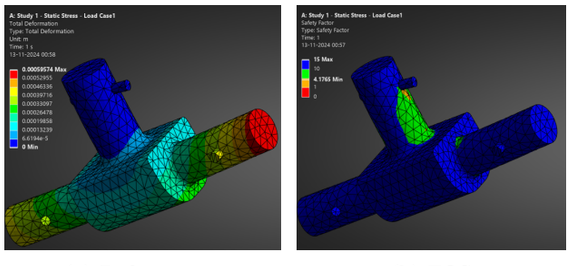


Figure 8: Battery Mount

Positioning the battery at the bottom of a drone lowers its centre of gravity, significantly improving stability and drone manoeuvrability during flight. This low placement also provides more space for electronic components, like sensors and other electronics, by keeping them higher up and easier to access. Additionally, bottom-mounted batteries often allow for quick access, making battery replacement faster and more efficient when the drone is in the field.

3.1.5. *Landing Gear*

For mechanical analysis, we have calculated a landing force of 50 N. This weight is distributed across the drone's T-joints, with each joint experiencing a force of 25 N. The load is evenly distributed and provides stability upon touchdown. The landing joint serves as the critical connection point between the base plate and the landing gear, ensuring stability and secure attachment during landing. Extensive simulations have been conducted to ensure the landing joint can withstand the loads effectively. The picture depicts the stress distribution at the bolt which mounts the vertical landing rod and the landing joint.



(a) Deformation (b) FOS

Figure 9: Landing Gear

3.2. ***Power and Propulsion System***

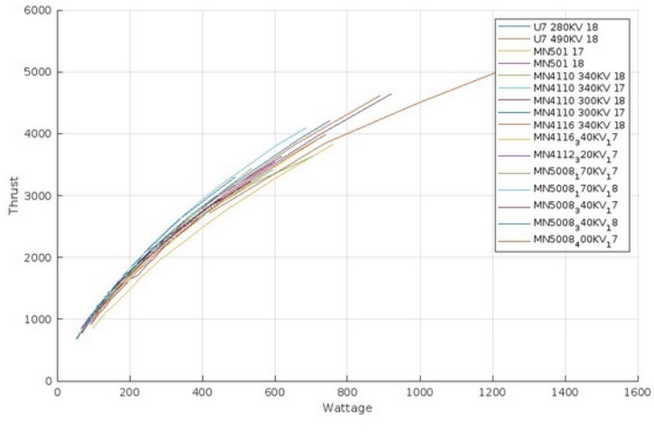


Figure 10: Power vs Thrust for Motor Comparison

The drone has an estimated weight of 4.5 kg and requires a total thrust of 12.6 kgf to achieve a thrust-to-weight ratio of 2.8. It is powered by *T-MOTORS MN4110 KV300* brushless motors paired with 18" diameter, 6.1" pitch carbon fibre propellers, chosen for optimal efficiency within the required thrust range. These motors are controlled by *AIR 40A 6S* Multi-Rotor UAV ESCs.

A single 6S 9000mAh Lithium-ion battery provides power to the four ESCs and Motors via an onboard power distribution board (PDB). Lithium-ion batteries are selected for their high energy density and suitable weight, providing a flight time of 20 minutes at a cruising speed of 5.2 m/s.

3.3. *Control and Communications Systems*

3.3.1. *Communication System Architecture*

To ensure consistent long-range bidirectional communication with the Base Station for real-time telemetry, we selected the RFD900x as our radio modem. This system easily integrates with the Cube Orange via MAVLink, providing a reliable data link even in challenging conditions.
Additionally, the *RP4TD ExpressLRS* mounted on the drone connects to a *FrSky Taranis X9D* remote control, allowing the spotter to take manual control if necessary in the event of an emergency.

The Rocket AC is used to transmit images, sensor data and depth information back to the base station. It serves as a high-performance wireless access point, and its powerful radio ensures exceptional data speeds and extended range. The Rocket AC offers various interference mitigation techniques such as Advanced Modulation Techniques, Frequency Hopping, Power Control, Channel Bonding, and high-gain antennas, making it suitable for areas with a high RF environment.

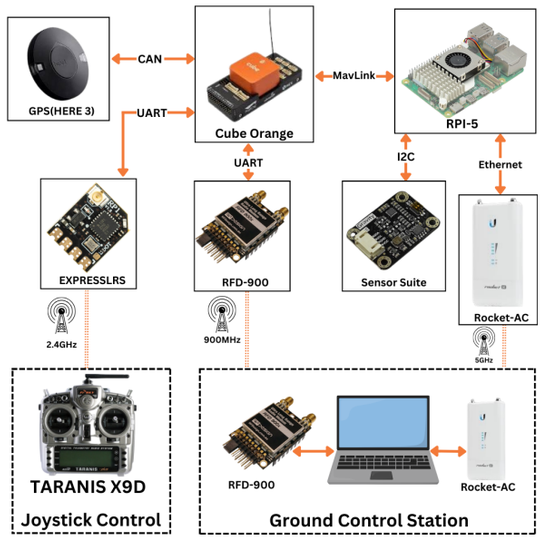


Figure 11: Communication System Architecture

3.3.2. *Autopilot*

In order to enable the drone to operate autonomously, we utilise the popular autopilot software ArduPilot Copter, which is known for its outstanding features including autonomous takeoff and landing, waypoint navigation and provides a comprehensive set of fail-safes. The flight controller of choice is the Cube Orange, which runs the autopilot firmware and maintains the communications links to the RC controller and the Base Station. The Base Station will consist of a computer running the Ground Control Software (GCS) which is connected to the cube via MAVLink. Our GCS of choice is Ardupilot Mission Planner, owing to its excellent compatibility with the ArduPilot Copter firmware and wide range of capabilities.

3.3.3. *PID Tuning*

PID tuning is the process of adjusting a drone's Proportional (P), Integral (I), and Derivative (D) parameters to enhance stability and control.

To ensure optimal control of the drone, extensive PID tuning was conducted for the drone's roll, pitch, yaw and throttle control. This fine-tuning was performed using post-flight log analysis tools that provided graphs of actual vs desired values of the drone's state. By reviewing these graphs, issues such as lag, overshoot, and oscillations were identified and adjustments to PID parameters were made in small increments, with further test flights and log reviews conducted. This iterative process ensured a smooth and stable flight performance.

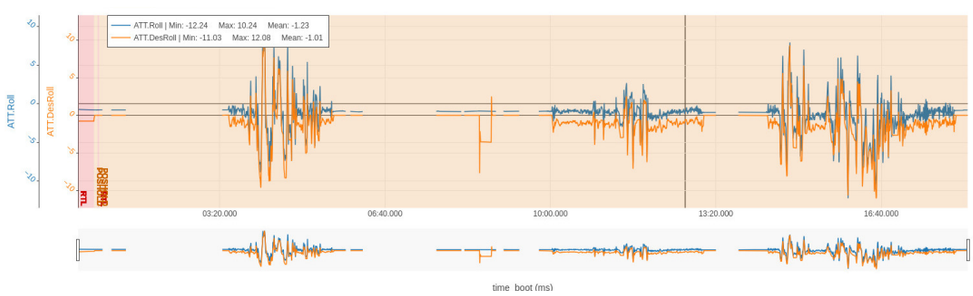


Figure 12: Sample Plot of Desired vs Actual Roll

3.4. *Sensor Data Collection and Analysis*

3.4.1. *Sensor Suite*

The drone's sensor suite was designed to allow a comprehensive collection of atmospheric data and images. To select the best sensors, we focused on reliability, accuracy, robustness and cost-effectiveness so as to ensure suitability for the specific conditions present in the simulated environment. Given that temperatures on Mars can vary from -153°C to 20°C, we also aimed to use sensors with built-in temperature compensation to ensure precise readings.(Refer to Table 2)

Function	Sensor Module	Specifications
Temperature	TMP117	• Range of -55 to 150°C • Accuracy of 0.1°C • 3V-5V
Pressure & Humidity	MS8607	• Accuracy of ±2 hPa, ±3% humidity • 3.3V or 5V
Gas Sensor	DFRobot Gravity MEMS Gas Sensor DFRobot Gravity O_2 Sensor SCD41 Infrared CO_2 Sensor	• Measures NO_2, CO, NH_3, O_2, CO_2 (ppm) • 3.3V or 5V

Table 2: Sensor Specifications

The onboard Raspberry Pi 5 facilitates onboard processing and storage of the collected data from the sensor suite. By measuring physical parameters such as temperature, humidity, and pressure, we can acquire a reliable estimate of the atmospheric conditions in the environment. Variations in these parameters across different locations and altitudes can provide valuable insights into atmospheric gradients, vital information to enable future expeditions to Mars.

3.4.2. *Camera*

The lightweight *Intel RealSense D435* depth camera captures depth and RGB data required to construct a ground terrain model of the Martian environment. It allows us to capture high-resolution (1280 x 720) pictures of the terrain, which can then be utilised for mapping.

4. MISSION PLANNING

4.1. *Navigation Mission Strategy*

4.1.1. *Current Mapping and Object Detection Strategies*

A three-dimensional model of the ground terrain must be dense and accurate in order to construct a proper path for the rover. At each instant, a limited field of view is visible to a camera sensor present on the drone. Therefore, the solution efficiently composes a single point cloud from a larger set while also running YOLO models to locate the markers spread over the area while staying within our compute restrictions.

Moreover, the pros and cons of each camera sensor need to be examined before picking one. Therefore, we created multiple simulations of drones, each with a different sensor. A sensor was judged based on its affordability and accuracy. The sensor data needs to be detailed enough to be able to conduct feature extraction for merging. Furthermore, we tried out several mapping algorithms on each sensor, such as Iterative Closest Point algorithm, ORB-SLAM2, MiDaS, OctoMap and direct superimposition of point clouds using odometry. After conducting extensive analysis on multiple sensors, we chose a Stereo camera, as unlike other sensors, it associates RGB data with each point while maintaining affordability, accuracy and output density.

4.1.2. *Navigation Stack*

To enable effective rover navigation, we designed an occupancy grid in ROS (Robot Operating System), which supports path planning with algorithms like A* and potential fields. ROS was chosen for its robust ecosystem of navigation and sensor integration, which is essential for easy and rapid development and reliable field operations. We integrated the navigation stack with the ArduPilot software via Pymavlink, a Python library for MAVLink communication, which allows real-time telemetry and direct control over mission parameters. For mapping, the extracted depth data is converted into a 2d Occupancy grid, which allows us to prepare a traversable map easily and obtain the least obstructed path for the rover.

4.1.3. *Coverage Planning Algorithm for Aerial Imaging and Stitching*

Figure 13: Coverage Mission

To optimize large-scale aerial coverage, we employ a grid-based approach, dividing the target area into cells corresponding to the camera's field of view (FOV). The drone follows a systematic back-and-forth path, known as a Boustrophedon path, traversing the grid with waypoints at cell centres, minimizing unnecessary travel. Images are captured at intervals of the drone covering half the cell width, ensuring sufficient overlap for accurate stitching. The Scale-Invariant Feature Transform (SIFT) algorithm identifies and matches distinctive features across images, while the Random Sample Consensus (RANSAC) algorithm filters out outliers, enabling precise image alignment. Multi-band blending seamlessly merges the images, creating a high-resolution terrain map ideal for in-depth analysis and large-scale mapping.

4.2. *Science Mission Strategy*

To effectively analyze the data received from the sensors, we leverage multiple machine learning and AI models to ensure insightful predictions:

- **Semantic Segmentation of Martian Terrain**
  We perform multi-label semantic segmentation, i.e. classify pixels in the images of Martian terrain using SegFormer models, which is a deep learning model that uses Transformers to capture the details of an entire image. The model accurately identifies features such as sand, soil, and rock, and achieves an accuracy of 90.86% on the AI4Mars dataset.
- **Segmentation of River Features on Mars**
  We utilise U-Nets, a neural network model used to separate features in an image, to segment river features on Martian terrain trained on a custom dataset from HiRISE images. The U-Net model marks areas like river channels, creating clear boundaries between the river and the rest of the terrain. This helps in accurately identifying river features on Mars.
- **Prediction of Surface Temperature**
  A Residual CNN-LSTM model is used to accurately predict Mars' surface temperature based on time-series data with features such as atmospheric pressure, sol (Martian day), and solar latitude. The CNN portion of the model helps to extract important features from the data, while the LSTM part captures patterns over time.

We also apply the same Coverage and Image stitching Algorithm used in the Navigation Mission(Refer to 4.1.3) to seamlessly stitch images of the surroundings at the three designated waypoints, enabling a thorough and detailed analysis.

4.3. *Emergency Procedures*

In the event of an emergency or catastrophic failure, we have employed a set of procedures to aid with recovery. These procedures are listed below:

- **Loss of Telemetry:** Triggers the Return-to-Launch (RTL) function on the drone. The spotter will monitor the drone's RTL progress and be ready to take control if needed.
- **Battery Issues:** The drone's battery level is monitored closely during flight. If the battery level reaches a critical level, initiate a safe return to home or landing as soon as possible. If the battery fails or drains rapidly, activate the emergency landing procedure available on the drone.
- **Flyaway:** In case of a flyaway, attempts will be made to regain control by reconnecting to the drone using the remote controller or the controller's RTL function.
- **Collision or Crash:** In the event of a collision or crash, the throttle will be immediately cut to prevent further damage to the drone. Damage to the drone's components, including the frame, propellers, and camera, will be checked by the standby runners.

5. TESTING AND VALIDATION STRATEGY

The success of our drone design relies on thorough testing and validation to ensure it meets performance and safety standards. This section outlines our strategy for testing individual components and the drone's overall functionality and reliability in various conditions.

5.1. *Subsystem Testing*

We have organised our testing framework into subsystems in order to improve testing efficiency, facilitate independent testing of major systems, and isolate issues specific to their respective domains.

- **Mechanical Subsystem:** Our objective was to minimise chassis weight while ensuring strength. We used Ansys for stress-strain analyses, maintaining a safety factor above 4, and evaluated 3D-printed parts for support structures, choosing materials based on durability and loading conditions.
- **Electronics and Communication Subsystem:** We developed a custom power distribution board (PDB) to efficiently manage current to each motor, optimising performance while providing overcurrent protection and voltage regulation. Extensive load and stress tests ensured the PDB met the demands in various scenarios. Additionally, we rigorously tested our communication system in high radio frequency environments, confirming reliable data throughput even under interferences.
- **Software Stack:** Extensive simulation testing with detailed terrain representations and real-world physics modelling was carried out in simulation software such as Gazebo and Unity. To test the versatility of the mapping and the navigation algorithm, the conditions were tuned to be in line with the actual Martian surface. Reliability of the stack was ensured by the use of the message parsing framework ROS which enables various tasks to be handled by distributed, and with backup nodes existing to take over in case a node malfunctioned. The terrain was prepared with attention to detail, and was iteratively tested with Depth, Monocular and Lidar sensors.

5.2. *Automated and Manual Testing*

Our testing approach combines automated and manual methods to evaluate the drone's performance under various conditions. We use simulation tools like Gazebo and Unity to test the navigation algorithms, sensor integration, and mission planning in virtual Martian terrains. Additionally, Hardware-in-the-Loop (HIL) testing integrates the drone's real hardware with simulated environments to validate control algorithms and sensor responses before actual flight.

For manual testing, we conduct real-world flight tests to assess the drone's stability, control responsiveness, and sensor performance in varied conditions. ArduPilot is used for real-time data logging during automated and manual tests. After each test, we analyse the logged data to identify performance gaps and refine both hardware and software, ensuring the drone meets mission requirements.

5.3. *Data Collection and Logging Techniques*

To ensure informed decision-making, we implemented advanced data collection and logging during our testing process. This was essential for gaining insights into our drone's performance and reliability. Our methodology included the following key components:

- **Real-Time Data Logging**: Flight data, including GPS location, altitude, speed, and battery levels, is continuously recorded and logged by ArduPilot during missions.
- **Post-Flight Analysis**: After each flight, we download the logged data and analyse it to evaluate the drone's performance and identify areas for improvement.
- **Telemetry Systems**: The telemetry system is central to monitoring and managing the drone's operation during flight in real-time. It provides both the pilot and mission control with a continuous stream of data, enabling informed decision-making and facilitating immediate corrective action when necessary.

6. PROTOTYPE DEVELOPMENT

6.1. *Manoeuvrable Drone Simulation*

To enable iterative testing of the software stack while the physical drone is being built, we developed a comprehensive simulation of a manoeuvrable drone with realistic physics and ground terrain in Gazebo. In order to assess the pros and cons of several sensor configurations, we created multiple versions, each with a different sensor configuration - 2D LiDAR, 3D LiDAR, monocular camera and a stereo camera. These sensors provide essential inputs for evaluating our various mapping algorithms, facilitating robust environmental reconstruction and localization.

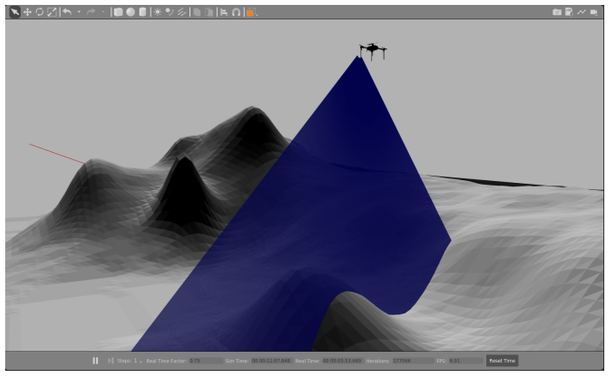
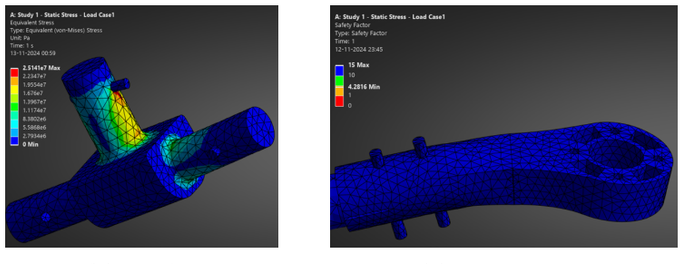


Figure 14: Gazebo Simulation

6.2. *Material Selection*

The UAV's main frame is constructed from CF for its high strength-to-weight ratio, providing a lightweight yet robust chassis. We use CF-reinforced nylon (CF nylon) for the mounts and joints due to its heat resistance up to 200°C and superior impact resistance. ABS and PLA were initially considered for the motor mounts and joints but were discarded in favour of CF-reinforced nylon (CF nylon) due to its superior temperature resistance, impact resistance and durability. This material allows for complex geometries through 3D printing while ensuring strength and functionality, enabling the drone to withstand stresses while maintaining efficiency and reliability. Below are the simulations of mounts and joints on CF nylon.

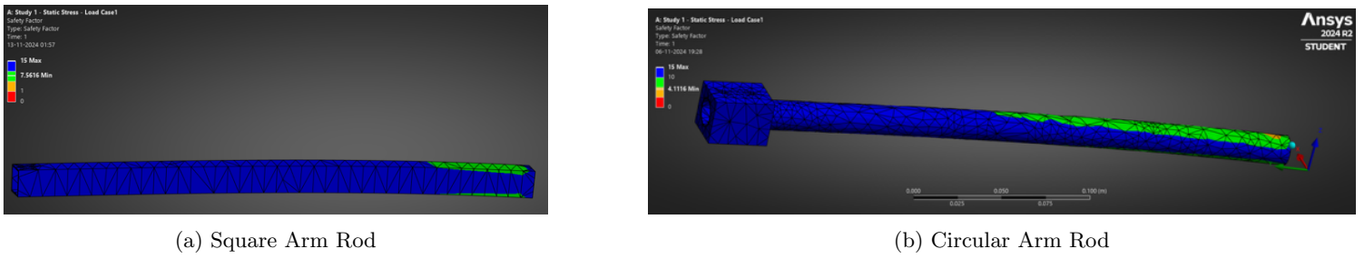


(a) T-Joint (b) Motor Mount

Figure 15: Ansys Simulations on CF Nylon

6.3. *Mechanical Design*

In the initial cases of the design process, square arm rods were considered for the drone as they exhibited better section modulus, leading to better bending resistance. Eventually, circular arm rods were adopted due to better stress distributions and budgetary constraints.



(a) Square Arm Rod (b) Circular Arm Rod

Figure 16: Square Arm Rod vs Circular Arm Rod

6.4. *Working prototype*

We used our prototype drone to verify the important communication functions of the flight controller and adjusted ArduPilot parameters, tested the landing gear with different configurations, designs, and materials to assess durability and response. Additionally, we ran Pymavlink SDK tests by deploying Python scripts on the Raspberry Pi, enabling efficient path planning and area coverage strategies. To ensure safety measures, we tested multiple emergency protocols, including response handling for telemetry and communication loss, to safeguard against in-flight disturbances.

We further optimised the drone's flight stability by testing various PID tuning techniques, combined with RC controller setup, to achieve precise control. For real-time data acquisition, we transmitted images and sensor data through RocketAC while also testing for the communication range and reliability, including RFD900x for telemetry, *Radio Master RP4TD Express LRS*, and Rocket AC.

Figure 17: UAV Prototype

6.5. *Current Status of the UAV*

Our current advancements reflect our commitment to enhancing the drone's operational capabilities while building up from the prototype and ensuring safety in various environments.

- The drone's design has been finalized, and orders for the carbon fibre components and filaments have been placed. Modifications have been made based on the results of testing conducted on the prototype.
- The OctoMap implementation is yielding good results, and is able to provide a good 3D model of the terrain. At present, we are working on further improving the algorithm and finding the best possible path through the model.
- The communication systems are operational and sensors have been finalised and are ready to order. Additionally, we have tested emergency procedures for telemetry loss to ensure readiness for potential challenges, including protocols for triggering the Return to Launch (RTL) function during lost link scenarios.

7. LESSONS LEARNT AND FUTURE WORK

7.1. *Project Implementation Lessons*

- Implementing a reliable communication strategy proved to be challenging. We drew inspiration from real-world applications like *NASA's Ingenuity*, as well as our previous projects. For instance, our initial data streaming strategy consisted of using a 4G module onboard the drone in order to transmit captured images, but the low bit-rate provided proved to be impractical.
- Our initial approach at mapping involved three methods - LiDAR, Stereo and Monocular Inputs. Extensive experimentation and testing with these sensors in ROS Gazebo revealed important insights into the challenges posed by using each sensor suite. For example, after developing a simulation for testing a 2D LiDAR, we learnt that it would need to be moved over the same area multiple times, increasing the total duration of the mission. Hence, we discarded this method.
- Our approach to sensor data processing initially involved onboard computing. However, we quickly realised that offloading this processing onto the ground station will dramatically increase our ability to analyse and operate on this data.

7.2. *Future Improvements and Spin-offs*

- The scope of the science mission can be further enhanced by the addition of a wider range of sensors.
- Improvements to the communications systems can facilitate longer range and lower power communications, for example, by utilising protocols such as Zigbee and LoRaWAN.
- Additional features and Mechanical modifications can be added to the drone to pick soil samples from the surface, which can then be brought back to the base station for analysis.

8. CONCLUSION

The *Project MANAS* team at MAHE has successfully developed an Unmanned Aerial Vehicle (UAV) prototype for ISDC 2025. The project involved multiple iterations and extensive research and testing to ensure compliance with mission requirements and safety. The team focused on the design, construction, sensor data collection, and software development for navigation and mapping. This report serves as a comprehensive overview of the Quadcopter design process, highlighting key decisions and analyses contributing to its successful development.